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OCEANUS

EDITOR: JAN HAHN

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Woods Hole Oceanographic Institution

WOODS HOLE, MASSACHUSETTS

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The cover design was suggested by Rear Admiral Edward H. Smith and executed by Mary K. Minot of Falmouth.

On August 16th the Board of Trustees of the Woods Hole Oceanographic Institution met at Woods Hole for their annual meeting and announced that the resignation of Rear Admiral Edward H. Smith, U.S.C.G. (Ret.) was accepted, and that Dr. Columbus O'D Iselin was appointed Director, to assure continuity in the administration during the planning and execution of oceanographic participation in the International Geophysical Year 1957-58.

Admiral Smith, having reached the retirement age, did not wish to remain in office beyond his six years term of appointment. Mr. Raymond Stevens, President of the Corporation, expressed the appreciation of the Trustees and stated that during Admiral Smith's administration the Institution expanded significantly, while the sources of interest and financial support for oceanography were broadened. It was largely due to his efforts that the Research Vessel CRAWFORD was acquired recently. The resolution also mentioned Admiral Smith's role in the establishment and growth of the Associates of the Woods Hole Oceanographic Institution, a group of private individuals, corporations and other organizations who aid in the support of scientific and educational work at Woods Hole.

Dr. C. O'D Iselin has been with the Institution since its inception in 1930. A student of Dr. H. B. Bigelow, first Director, he started his oceanographic career on an expedition to Labrador in his own schooner "Chance" in 1926. In 1931 he took command of the Research Vessel ATLANTIS on her first cruise in the North Atlantic after the ship was built in Denmark. Dr. Iselin served as Director during the war years and resigned in 1950 to devote more time to scientific studies. He served on the National Research Council Committee appointed to advise the U. S. Navy on the application of science to undersea warfare. In 1948 he was awarded the Legion of Merit for: ---"his prudent foresight and skill in the development of methods which saved a large number of our ships during the war." He was elected to the National Academy of Sciences in 1951 and received the Agassiz Medal, highest award for oceanographers in this country. Brown University awarded him an honorary degree in 1948.

Since 1950 Dr. Iselin has divided his time as Senior Oceanographer at the Woods Hole Oceanographic Institution, as Associate Professor in Physical Oceanography at Harvard University, and as scientific consultant and advisor to the government.

Where are the ships?

The ATLANTIS (Captain W. Scott Bray) and the BEAR (Captain Eugene J. Mysona) returned in June from a geophysical operation on the Blake Plateau, working out of Charleston, S. C. for Dr. J. B. Hersey and his group. Shortly after return to Woods Hole the ships left on a geophysical and geological cruise to the Caribbean Basin. This cruise is a continuation of the studies made by Dr. C. B. Officer during the early months of 1955 which were described in OCEANUS III, 3. Two scientific papers have already resulted from that work and will be published shortly in the Bulletin of the Geological Society of America.

Dr. Officer and John Ewing, chief scientist on the ATLANTIS, are trying to determine the crustal structure in the Eastern Caribbean, the Puerto Rico Trench and the Island Arc of the Caribbean Basin. The aim is to determine how this structure originated, if and how it differs from the North Atlantic Basin and what sort of geological development is going on in the area. So far, it has been found that the area is an altered portion of the Atlantic Basin. The crustal structure has been determined and the problem now is to try to put all the observations together to obtain a consistent picture of the geological origin and development of the region. The work is supported by funds from the Office of Naval Research and from the Bureau of Ships, U. S. Navy.

It is interesting to note that with the exception of the chief scientists and Mr. Richard Edwards the scientific parties on both ships consisted of Associate Professors, instructors, graduate students and students from Rice Institute, Harvard, M.I.T., Princeton, Columbia University, University of Wisconsin, Cornell and the University of Utah.*

The CARYN (Captain Robert G. Munns) has made several cruises to set out and recover drift buoys and anchored buoys. A longer voyage was made to the West In-

* Ed. Note to Alumni: No significance should be attached to the order of enumeration, with the exception that the largest detachment came from Rice Institute.

The Research Vessel Crawford departing Woods Hole on July 3 on her first cruise to study the "Birth of a Hurricane."

dies for Mr. L. Valentine Worthington in his continuing investigation of the cold deep water of the North Atlantic and its rate of overturn. One cruise was made for Dr. George L. Clarke, described on page 17 of this issue.

TEXAS TOWERS

On July 26 the CARYN left on a short cruise to Nantucket Shoals with Dr. John M. Zeigler to make a thorough survey on the site of Texas Tower number 3. The existing tower on Georges Bank is number 2, while number 1 has not been erected. Since 1954 this Institution has been investigating sites for proposed Texas Radar Towers off the northeast coast. Senior Oceanographer C. O'D. Iselin is in charge of the consulting work and provided oceanographic information which influenced the design and location of the structures.

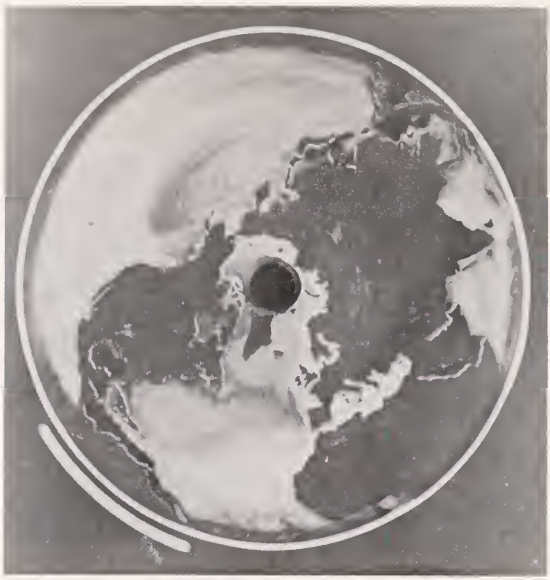
Hurricane Research

The research vessel CRAWFORD (Captain David F. Casiles) departed Woods Hole on July 3 and worked eastward of the Caribbean Sea to discover the "Birth of a Hurricane." Mr. Colin D. Macafee was chief scientist.

The ship was commissioned during the Annual Associates Day on June 30th in the presence of many Associates and their friends who afterward took a short cruise on the ship to Vineyard Sound. Senator Theodore Francis Green of Rhode Island, who has been most active in the promotion of hurricane research, was the principal speaker. During the cruise the senior Senator released the first weather balloon from the top deck of the ship.

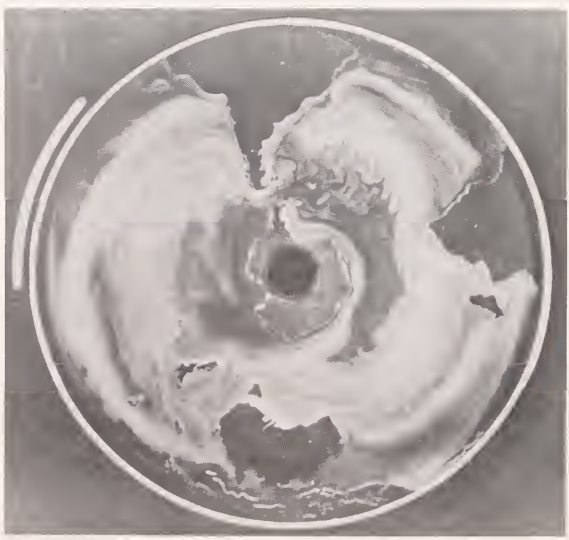
During August the ship worked together with our PBY (Captain Norman Gingrass) just north of Puerto Rico. Dr. Joanne S. Malkus, Mr. Andrew F. Bunker and Mr. Claude Ronne made meteorological observations on board the plane.

The ship returned to Woods Hole on the 8th of September.



A photograph of the 8-foot model showing the general circulation of the Northern Hemisphere. The Gulf Stream is shown as an irregular gray band along the east coast of North America and across the North Atlantic toward Ireland. The Sargasso Sea is the lighter gray area extending as far south as the Antilles. The lightest area south of Spain and west of Africa is the region of the North Equatorial Current which ultimately enters the Caribbean and feeds the Gulf Stream.

A photograph of the 8-foot model showing the general circulation of the Southern Hemisphere. In this part of the world there are two clearly different patterns of motion. In the Southern Ocean, which surrounds the Antarctic continent, the flow is driven by the west winds toward the east except at the coast line where the polar easterlies drive water westward into the Weddel and Ross Seas. In higher latitudes the circulation is almost closed as it moves around the South Atlantic and the Indian and South Pacific Oceans.



A Small World

by William S. von Arx

Too large an ocean, too few oceanographers. A miniature world has been built at Woods Hole to aid in the explanation of some problems.

Jonathan Swift touched a universally responsive spot when he placed his readers in the position of Gulliver in Lilliput. There is a certain appeal in miniatures of objects which arises perhaps as much from the flexibility of perspective and delight in fresh impressions as anything else. This very feature of engineering and research models is often as important as the quantitative data they may yield. In the case of phenomena occurring on a global scale these impressions are essentially all we have. Unfortunately, natural processes which are too large, too slow, or beyond the reach of observing instruments, do not necessarily yield up their secrets in models. In fact it is rarely possible to design a model which will represent more than a few of the important contributing influences in a natural occurrence. Even so, experimental models can sometimes provide an animated physical impression of these few phenomena which lie beyond the range of ordinary human experience, and often serve as a proving ground for analytical thought. If the model is reliable and representative, insofar as it goes, one can gain from it a fair idea of not only how, but when an observational program may be conducted in the field and where on the earth the most significant data may be collected.

These are some of the considerations which have prompted experiments with ocean models.

The Modeling Problem

Just at present we are almost as much concerned with models themselves as with the results they produce. This is a natural stage in the development of any technique. In scaling the motions of the earth's fluids down to laboratory dimensions we try to make the model forces, evaluated in terms of model length and time, have the same numerical value as their counterparts in nature measured in ordinary units. Simple though this is in principle, the scaling procedure is often thwarted by the pull

of gravity and the properties of materials, like viscosity, which cannot be changed appreciably.

Because of this, the construction of a satisfactory model of an ocean requires first of all a selection of a few of the many physical parameters which are known to influence the ocean circulation. For example, the oceans are partly heat-driven, responding mechanically to the difference in solar heating be-

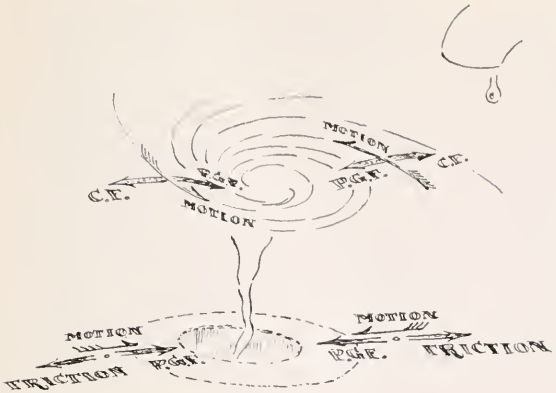
The 8-foot rotating tank apparatus in which the experiments shown on page 4 were made.

tween the equator and poles, and partly wind-driven; the atmosphere performing this function of transforming thermal energy into mechanical energy. In addition to heat, wind, or both, one also has to provide experimentally the effects of the rotation and curvature of the earth.

In our laboratory experiment the effects of earth rotation are present, but by rotating the experimental apparatus much faster than the earth does, far stronger rotational forces are produced so that the earth's effects can be neglected. Freely moving objects like streams of water and puffs of smoke follow familiar trajectories when moving across the laboratory when we watch them in the ordinary way, but to an observer standing on the rotating apparatus these paths appear to be very strongly curved. The apparent curvature can be thought of as being produced by a force acting horizontally and at right angles to the direction of motion of the particles involved.

This is the familiar Coriolis force that deflects the plane of vibration of the Foucault pendulum, and causes the shells of northern hemisphere cannon to fall to the right of the aiming point. Some say it also causes rivers to wear away one bank more than another and makes water spiral down the drain more often one way than the other, but these latter effects do not emerge at all clearly from the background of chance occurrences. In everyday affairs the effects of the Coriolis force are mainly lost in a confusion of friction and many other forces of local origin.

In our laboratory model water does go down the drain the same way every time; namely, in the same sense of rotation as that of the model apparatus. In this case it is the Coriolis force, the deflecting force of rotation, that is responsible for the sense of spin because it has been made strong enough to hold out



THE KITCHEN DRAIN.

The familiar circumstance of viscous gravity flow on the bottom is contrasted with cyclostrophic flow in the whirlpool at the surface. In viscous gravity flow the pressure gradient force P.G.F. is balanced by friction, while in cyclostrophic flow it is almost entirely balanced by centrifugal force labeled C.F.

against the unenhanced opposition.

We accept without question the statement that water flows downhill; that is, down the gradient of pressure. Rivers and streams all do this, water supply systems are designed on this principle, and yet we have only to pull the plug in the kitchen sink to arouse some doubt. The downhill direction from any point near an open drain is most certainly toward its center, and yet more often than not the water spirals around the hole nearly across the gradient of pressure.

The difficulty here is that the initial statement is incomplete. It refers to flow that is dominated by friction. Deep water tends to gyrate on its way through household drains because every chance bit of net angular momentum in the water tends to be conserved. Thus as particles from some distance away approach a drain, their radii of gyration are shortened and their angular velocity becomes conspicuously large. But at the bottom or in very shallow water where friction is more important, the motion is nearly straight toward the hole. In friction layers like this, and out of doors wherever winds and ocean currents are heavily impeded by friction, air and water tends to move down the gradient of pressure. But high in the air and far at sea where friction is slight, fluid motion is more commonly across the gradient of pressure.

To have the motion proceed in this fashion something must balance the thrust of the pressure gradient. In the case of the kitchen sink where the earth's rotation is quite unimportant, the balancing force directed away from the drain is centrifugal force; the thrust we feel urging us outward when we make sharp turns at high speed. In the ocean and atmosphere, however, the curvatures of wind and water flow are generally not sharp enough for centrifugal force to be conspicuous and it is the Coriolis force — the deflecting force of the earth's rotation — that balances the pressure gradient

force. When centrifugal force does the balancing we have what is called cyclostrophic motion, found alike in kitchen sinks, tornadoes, and some tropical cyclones; but when the Coriolis force is the predominant balancing agent the motion becomes geostrophic. It is this class of balanced flow across the pressure gradient that is most often encountered in the open sea and in everyday winds of the upper air.

This pressure is produced by the difference in water level between the Sargasso Sea and the Slope Water. The Sargasso water on the high side is, less dense — saltier but warmer — than that on the low pressure side. Naturally the high pressure water tends to flow toward the region of lower pressure but once in motion, the Coriolis force turns the flow to the right (in the northern hemisphere) until the direction of flow is

This bird's-eye view of the Atlantic coast north of Cape Hatteras shows how the pressure gradient force P.G.F. produced by the mass of warm light water in the Sargasso Sea is balanced by the Coriolis Force accompanying the motion of the Gulf Stream. The Gulf Stream can be regarded as fluid dam holding back the flood waters in mid-ocean. Actually were this dam to give way, the sea level along the coast would rise less than a meter, but the flood water would be warm and relatively lifeless so that fishing would not be very good for some time.

Because of the earth's rotation each geostrophic current in the real oceans and in models becomes, in time, associated with a field of pressure across the direction of flow. The Gulf Stream, for example, flows along the western edge of the Sargasso Sea where there is a field of pressure across the current. parallel with the Gulf Stream and the outward flow stops. In this fashion the Coriolis force balances the pressure force, or vice versa, and the high pressure region is separated from the low pressure region by the effects of earth rotation on the moving water between them.

Friction destroys the perfection of this scheme and indeed, though water is a very slippery substance it does not slide over itself with perfect freedom. Therefore, ocean currents hardly ever flow exactly at right angles to the pressure slope and there is some leakage across currents. This imperfection is further exaggerated by the fact that ocean currents are not smooth and steady.

The Gulf Stream, we have learned, flows in a pulsating fashion, and it also meanders from side to side of some mean course that is only approximately known. Moreover, the individual current pulses tend to form disconnected ribbons some fifty to one hundred miles long. The two modes of flow — meandering and pulsation — are not mutually exclusive, but no one has any clear idea of how they are related.

Presumably the average motion of the Gulf Stream is sufficiently fast to hold back the high pressure of the Sargasso Sea from the lower pressure of the Slope Water along the Continental Shelf, but the faster pulses, deflected by the Coriolis force, could climb the average pressure slope into Sargasso Water and the slower portions of the current could be thrust toward Slope Water. This process would tend to form meanders, and perhaps initiates them. Once formed, the meanders probably grow by other mechanisms because the meanders and current pulses move at different speeds. Both pulsation and meandering appear spontaneously in the rotating apparatus and there is hope that the new 4-meter tank will permit these relatively small details of the major currents to be studied experimentally.

Dr. von Arx came to the Institution a little over ten years ago with an interest in the large scale ocean circulation. He devised an electromagnetic method for detecting the surface structure of ocean currents as the ship sails through them, and a wide field camera to photograph from aircraft the features of the sea surface and clouds. During recent years he has been working chiefly on model techniques.

Seasonal Changes

Changes in flow rate can be reproduced in the rotating tank apparatus through a change in wind speeds. But there is more to it than this. The simulated winds reproduce much of the ocean circulation and water mass structure when the tank is filled with ordinary homogeneous tap water. This is suggestive in that written statements often point out with care that the ocean currents are associated with the boundaries of the principal water masses of the oceans. From this laboratory experiment there seem to be grounds for considering the pattern of water mass distribution of the oceans to be consequent upon the pattern of the wind-driven circulation. In other words, the atmospheric circulation determines the ocean current pattern which in turn determines the geographic distribution of water masses.

In nature the water masses of the upper layers of the oceans have properties which are determined by the predominant climate of each wind zone. But the oceans themselves influence this climate and the pattern of wind zones, and here we are at the beginning once more. In tracing out this circle we have not gained very deep insight into the essential problem, except to identify a "feedback" situation and to realize still more clearly that the oceans cannot be studied out of the atmospheric context.

Because of the complexity of the interaction between the oceans and atmosphere it is profitable to study this in the laboratory where each of the effects can be isolated. For example, we have already shown that the effects of equatorial heating are not necessary to the production

The 4-meter (13.12-foot) rotating tank apparatus. The white surface is the model area, surrounded by a ring of fluorescent lights to provide shadowless illumination for the cameras mounted on top of the tripod, and a ring of blower nozzles and infra-red heaters for simulating the planetary winds and sun's heat. This apparatus floats on water so as to run level and with perfect smoothness; a difficult thing to achieve with mechanical supports.

of a recognizable oceanic circulation pattern. But at the same time we have found that a small change of the wind pattern, such as that which occurs with a change of season, produces effects in the laboratory which are much too large and too rapid to correspond with those in nature. This suggests that the contrasting density of heated water in mid-ocean with that around the edges and beneath tends to slow the response of the real oceans to seasonal changes in the wind distribution. One can see why this may be so because the high pressure body of warm salt water in the central ocean is built up slowly, storing energy in times of strong atmospheric circulation which would otherwise appear as water motion. In leaner times, or were the winds to cease altogether, the flow of high pressure water would be deflected by the earth's rotation in a manner tending to maintain the circulation in nearly its original form. In this fashion, the water mass and pressure distribution systems associated with the major ocean currents, function as a kind of "flywheel", resisting change of speed and tending from season to season to suppress the effects of short lived extremes of wind and weather.

In an attempt to study these effects the new apparatus is equipped with infra-red heaters which are designed to warm the model oceans most intensely at low latitudes as the sun does. Infra-red of the wave lengths produced by such heaters is almost completely absorbed in a layer of water no thicker than this paper. This thickness is roughly in proper scale relative to the depth of water in the model to reproduce the depth of direct solar heating in nature. While the model oceans are about 100 times deeper than they should be on strict geometrical grounds, the relationship of their thickness to this penetration of heat and to the thickness of the so-called "friction layer" is about the same as in nature The theory of the two layer ocean is still in its earliest stages of development, and the physical consequences of surface heating in a rotating model are at the moment even more obscure, but with a few experiments to guide our thoughts some understanding may be forthcoming. This and the problem of unstable flow in swift major ocean currents are among our targets for the near future.

The Ultimate Experiment

In the distant future, if all goes well with the heating experiments, it may be possible to model the atmosphere in a heavy gas overlying the ocean model. If this gas is transparent to the infra-red heater radiation but opaque to the lower temperature radiation of the ocean model (as carbon dioxide would be) the radiant heat would penetrate the gas to the ocean surface and heat the model atmosphere from below. Sunlight heats the real atmosphere by similar

An oblique view of the frontal convergence along the western edge of the Gulf Stream showing how complex it can become and how far ahead it can be traced. Fluorescein dye packages dropped on lines at right angles to the front make spots which move toward the convergence rapidly as they drift with the main current.

secondary processes. It is just possible that the motions of this gas could be made to resemble those of the atmosphere and with sufficient strength to drive the ocean model. The ocean currents would then carry heat into high latitudes and cool water into low latitudes in a manner resembling nature to produce some properties of the "feedback" system mentioned earlier; probably the most complicated system in planetary fluid motion. Such an experiment must wait, intriguing as it may be, because the results could be no less than bewildering until our minds are better prepared.

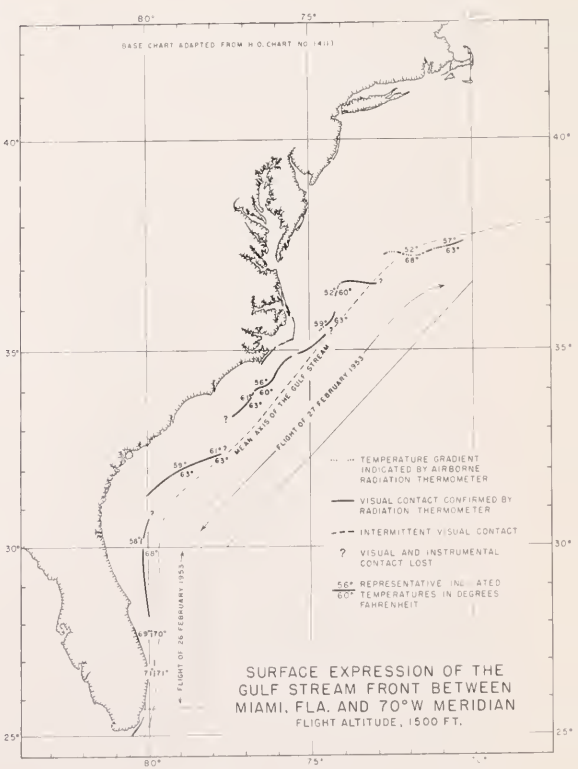
Such preparation requires intensive study of the atmosphere as well as of the oceans, partly by means of models. The laboratory formerly used for ocean models is now being used by Alan J. Faller for atmospheric motion experiments. These experiments are directed toward a study of the quantitative effects of heating on the general atmospheric circulation. Faller's model consists of a rotating tank partly filled with water to represent a hemispheric shell of the atmosphere. The water is heated from below near the rim, and cooled from below at the center. Due to the rotation of the tank the rising warmed water at the rim does not move toward the center but around the center as a strong narrow current flowing in the direction of motion of the tank. Under proper conditions this current develops waves very like those of the atmospheric jet stream and this jet stream is correctly associated with polar outbreaks of cold water bordered by sharp fronts. Cyclonic disturbances develop on these fronts and move along them in much the same way as cyclonic centers develop and progress across our daily weather maps. Study of the response of this kind of system to heating variations of seasonal character,

and to non-uniform heating like that occasioned by the alternation of land and ocean surfaces around latitude circles of the earth, has direct bearing on an ultimate understanding of the ocean-atmosphere system.

Ye Gods

As we work with models of the oceans and atmosphere there are moments when it becomes easy to understand the prankish diversions of the gods of ancient Greece. A mere twist of a knob and there is mortal chaos below. The chaos we can create in the models teaches us something about the sensitiveness of the earth to change, and what conditions might be like under other circumstances — on other planets or in time past. In 1929, P. Lasareff published an estimate of the ocean current systems of the geologic past obtained by blowing trade winds over models of the strange configurations of land and sea that are presumed to have existed on the earth. Fultz, at the University of Chicago, has produced regimes of atmospheric motion that might exist on other planets. With such flexibility at our disposal under conditions where thorough physical and mathematical digestion is possible, it seems clear that models offer opportunities for intensive and extensive study of very large scale phenomena and a chance to sharpen our older tools against the grindstone of experiment.

A chart of the western edge of the Gulf Stream traced by flying over frontal convergences. The curious result of this experiment is the discontinuous and offset character of the frontal pattern. From this and evidence obtained by repeated crossings of the current with one of our ships we are led to believe that the Gulf Stream is neither steady nor continuous but consists of a succession of overlapping streamers. The current may be broken up in this way by the rise and fall of the diurnal tide in the Gulf of Mexico.



Associates News

Life Membership

IN the 1956 Spring Issue of Oceanus it was announced that a Life Membership had been established. We are pleased to report the following Life Memberships since May:

Mr. and Mrs. F. Harold Daniels.	*Worcester, Massachusetts.*
Mr. and Mrs. Henry Hotchkiss.	*Martha's Vineyard, Massachusetts.*
Mr. and Mrs. Henry S. Morgan.	*New York, New York.*
Mr. and Mrs. Donald B. Straus.	*New York, New York.*
Mr. Henry B. duPont.	*Wilmington, Delaware.*

New Corporate Associates

American Bureau of Shipping.	New York, N. Y.
Atlantic Mutual Insurance Company.	New York, N. Y.
Farrell Lines, Inc.	New York, N. Y.
Hartford Fire Insurance Company Group.	Hartford, Conn.
Liberty Mutual Insurance Company.	Boston, Mass.
Sangamo Electric Company.	Springfield, Illinois
Western Electric Company, Inc.	New York, N. Y.

Associates Fellowships

1956-57

Funds from the memberships fees of the Associates of this Institution were set aside last year for annual grants to promising college graduates who have shown a keen desire to pursue education in the earth sciences.

One Fellowship was awarded last summer to Mr. Roderic B. Park, who is pursuing his studies at the California Institute of Technology. Mr. Park's Fellowship recently was renewed for another year. Two other Fellows were appointed at the same time. They are Mr. Duncan C. Blanchard* of this Institution who has been working with Mr. A. H. Woodcock since 1951, and Mr. Edward D. Stroup of the Pacific Oceanic Fishery Investigations, U. S. Department of the Interior, Fish and Wildlife Service, Honolulu, T. H.

Duncan C. Blanchard has been with the Institution since 1951 working with A. H. Woodcock and A. T. Spencer. Together they have made many field trips by airplane and other means to chase raindrops and salt particles from Hawaii to the Virgin Islands.

His degrees include a Bachelor of Naval Science from Tufts College in 1945, B.S. in General Engineering from Tufts and a M.S. in Physics from Pennsylvania State University in 1951. He has published twelve scientific papers on raindrop size and distribution and on the behavior of water droplets. This work was described in the Spring 1956 issue of OCEANUS and in the July 7 issue of the *Saturday Review*. During recent years he has also been interested in the electric charge transfer process between the sea and the atmosphere and what role breaking bubbles at the sea surface play in this process.

Mr. Blanchard will do his graduate studies in the Department of Meteorology at the M.I.T., starting this autumn and plans to work at Woods Hole during the summer months.

Edward D. Stroup, born in Honolulu, attended the University of Washington in Seattle and the University of Hawaii. Starting in marine biology he switched to physics major and received his

* See OCEANUS IV, 3. pp 21-24. "The Fingerprints of a Storm".

B.A. in June of this year. Since 1951 he has worked part-time during the school years at the Pacific Oceanic Fishery Investigations. His sea-going experience includes seven major oceanographic cruises and some shorter trips. Moreover, as he pointed out: "coming from Hawaii I have been in, on, around and under the water most of my life".

Mr. Stroup has published a report on one of the Equatorial Cruises with T. S. Austin as co-author, and a Review of the Oceanographic Programs of the Pacific Oceanic Fisheries Investigations, published in the *Transactions of the American Geophysical Union* With T. Cromwell and R. B. Montgomery he published a preliminary report in *Science* on the Equatorial Undercurrent in the Pacific. He has also read papers at scientific meetings in Hawaii.

A photographer and a charcoal broiler of turkeys, Mr. Stroup may have to forget his third hobby of surf swimming for awhile as he intends to use the Fellowship to study physical oceanography at Johns Hopkins University.

What, no sea serpents?

What are we looking at? Or, who's looking at us? It is the underside of the head of a small shark belonging to the family Oxynotidae, of which only one genus with three species are known, two in the Mediterranean and one in Australian water. They grow to about three feet. The very rough skin and peculiar teeth are not possessed by any other shark.

The shark is being studied by Dr. H. B. Bigelow and Mr. William C. Schroeder for a paper on spiny ray sharks. The well known spiny dogfish is included in this group.

Light in the Deep.

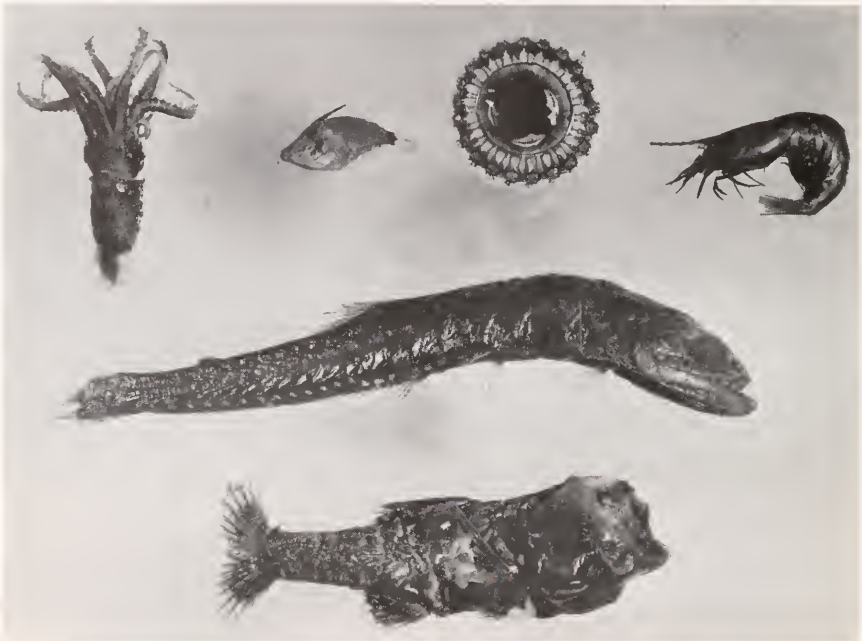
by George L. Clarke

Light is essential to life. The conditions of light in the deep sea have been a matter of speculation for years. A new instrument has made it possible to measure light to a depth of more than one mile.

THE penetration of light into natural waters is of vital concern not only for the growth of green plants but also for the photic reactions of animals. In addition, a knowledge of water transparency has many practical applications, for instance in salvage work and underwater photography or television. Measurements made for many

years have provided us with considerable information on the intensity and quality of light in the upper water layers during the daytime, and its ecological significance.

Most pelagic or free swimming animals in the ocean



A haul from the deep sea. Note luminescent organs along the bodies of the fishes.

and in lakes are limited in their vertical distribution to definite ranges of depth, and many kinds of zooplankton and fishes are known to undertake characteristic vertical migrations downward to lower levels in the early morning with a return to higher levels in the evening. This diurnal migration appears to be more closely correlated with changes in the strength of the light penetrating from the surface than with any other known factor of the environment. In certain instances in which the vertical migration was confined to relatively shallow depths, measurements of the illumination in the water have been made at the same time that the positions of the animal populations were determined by means of plankton hauls.

However, photometers of the usual type containing photovoltaic cells are not reliable for the measurement of intensities less than about 0.01% of sunlight. This means that with this type of photometer the relation between light as an ecological factor and the activities of migrating animals cannot be directly investigated at depths

greater than about 180 to 250 feet even in clear waters. At greater depths or in less transparent water a more sensitive photometer is required, or else reliance must be placed on an extrapolation of the diminution of light assuming that the extinction rate in the deeper water is the same as that actually measured near the surface. Such an assumption might lead to highly erroneous results.

In the ocean beyond the edge of the continental shelf net hauls have shown that certain species of crustacea carry out diurnal migrations, the lower limits of which are as great as 2500 feet. In addition, echo sounder records have revealed the widespread occurrence in the sea of "deep scattering layers"*, commonly at depths of 1200 to 1800 feet during the daytime but also sometimes as deep 3000 feet. These layers typically migrate vertically hundreds of feet each day. Although it is difficult to determine what kinds of animals are primarily responsible for sound-scattering, it seems probable that the small shrimp like euphausids and fishes are involved in at least some of these layers. Very likely concentrations of other animals, some of which do not reflect sufficient sound to be recorded by present equipment, are living at various levels in the ocean and are carrying out similar or perhaps even more extensive migrations, as yet undetected.

* See: Oceanus III, 1. "Sound in Marine Research"

Dr. George L. Clarke, Marine Biologist on our staff since 1931 is Associate Professor of Zoology at Harvard. He took part in the maiden cruise of the ATLANTIS and is the author of "Elements of Ecology" published by John Wiley & Sons in 1954.

New light meter

The construction of photometers containing extremely sensitive photomultiplier tubes has made possible the direct measurement of light at the depths at which the deep scattering layers are found in the ocean and hence has opened the way toward a more exact study of the role of light in the control of diurnal migration. Last year, Gunther K. Wertheim, and the author designed a bathyphotometer which can measure light as faint as 0,000,000,001 percent of full sunlight, as found at ocean depths of about 2000 feet. The response of the instrument can be read directly on board ship with the aid of a recorder.

Luminescent flashes

Many animals living in the deep sea have light producing organs, sometimes arranged in rows along the body, at other times along the jaws and on the head.

An impression of the abundance of luminescent animals in the sea and a measurement of the intensity of their luminescent discharge was

obtained by lowering the bathyphotometer at night. When the instrument was suspended below 600 feet, the light meter recorded large but very brief increases in current at regular intervals. At greater depths the flashes increased until at about 900 feet flashing was practically continuous.

Below 900 feet the general illumination from bio-luminescence at night became greater than the light reaching this depth from the surface during the day. Individual flashes were as much as 1,000 times brighter than the background illumination. As yet we do not know whether large flashes were caused by brilliant luminescence at some distance or by weaker discharges near the instrument, but we hope to eliminate this uncertainty in the future.

This year an improved model of the bathyphotometer has been built by Charles J. Hubbard. The new instrument is provided with a simplified electrical circuit, a greater length of cable, and a housing capable of withstanding pressures at greater depths. On a recent cruise of the CARYN the new bathyphotometer was used successfully to depths greater than 5,500 feet or just over a mile. A record was obtained of the diminishing light from the surface and of the flashes of luminescent animals. The observations showed that luminescence exists at night at all levels but that the flashes vary in intensity and in frequency at different depths. During the day luminescent flashing was observed at all levels below those where daylight would obscure it.

Since our records at a depth of one mile show flashes occurring as frequently as five or more per second, we now know that the deep sea is not continuously enveloped in inky blackness but at times, at least, must present the appearance of the night sky on the Fourth of July.

THAR GOES FLUKES!

Last April three Right Whales cavorted for about one week in Menemsha Bight off nearby Martha's Vineyard. Through Mr. Stanley E. Pool's initiative it was possible to record the underwater sounds made by the whales near the launch Risk. Heretofore it had not been definitely established that baleen whales make sounds, although many recorded noises of toothed whales are in the files of Mr. William E. Schevill.

Right Whale having just surfaced to blow. Note blow-holes closing just behind the 'bonnet", a characteristic feature caused by parasites. Gay Head Lighthouse in the background and the Risk in right foreground.

Below: Showing flukes as one of the smaller whales sounds in about 45 feet of water, and a model of a Right Whale.

American Museum of Natural History

David Frantz, in the typical oceanographer's pose, fastens a line to a radiotelemetering buoy.

Drift Bottles are getting bigger

by Dean F. Bumpus

ONE of the drawbacks of conventional drift bottles is that one does not know where they have been between the point of launching and the point of recovery, nor is there any indication on variations in the speed of drift. A "drift bottle" has been developed which is kind enough to show its position when asked to do so from shore, ship or airplane.

Our electronics shop, under the leadership of Robert G. Walden, has successfully developed and tested at sea a radio-telemetering drift buoy as a means of studying non-tidal currents in the sea. This is essentially a spar buoy drawing 19 feet with one foot freeboard and a whip antenna which transmits radio signals of 15 seconds duration for direction finding purposes whenever it is keyed by radio from ship, aircraft, or Woods Hole.

On 12 June one transponding drift buoy was set adrift 30 miles west southwest of Gay Head, Martha's Vineyard. During the following two weeks the position of the buoy was determined as often as weather conditions and other

commitments of our aircraft permitted. The buoy was located by homing on it with an airborne direction finder using a "spiraling in" procedure, until it was obvious that the buoy was in the immediate vicinity. We then endeavored to locate the buoy visually. This latter endeavor was not always successful owing to the small size of the above-surface portion of the buoy. In the future we plan, for daytime observations, to secure a large orange plywood panel to the buoy and, for night-time observations, to place a small lamp on the buoy which will light up when the buoy is triggered. We hope this will aid in making visual contact.

In the course of the fifteen day period of drift the buoy was located seven times. It was last located within seven miles of its starting position, but in the course of time had drifted throughout at least one clockwise rotation having been 18 miles to the east southeast and 21 miles to the west southwest of the initial position while on this circuit. The buoy failed to respond after 1345 on 26 June while our boat ASTERIAS was enroute to recover it. A visual search of the area was unsuccessful.

Oceanographer Dean F. Bumpus has been with the Institution since 1937 and has actively studied inshore water masses. At present he is in charge of the investigation of climatic and oceanographic factors influencing the environment of fish.

Two weeks later we learned that a Navy tug towing a target had knocked the antenna off the buoy at 1420 on the 26th of June, only 35 minutes after the last successful transmission from the buoy. This casualty to the buoy had been witnessed by a Destroyer Escort which picked up the buoy and eventually returned it to us.

The indicated rates of drift of the buoy are of interest. Following a relatively slow northward drift on the first day, the buoy moved southeasterly at the rate of fifteen miles per day, thence westerly and southwesterly at decreasing rates. During the last week, with fixes on the 18th and 25th, the drift was north northeast at only two miles per day. It is possible that, had fixes been made more often during the last week the rates of drift would have been larger, for we have no reason to believe, on the basis of the buoy's drift during the previous

week, that it went directly to the last observed position.

We have noted no phenomenon in the tidal cycle locally which would be suggestive of the cause for the sudden speedy drift with a gradual recovery to the more expected rate. We believe the tidal cycle in these waters to be rotatory at rates somewhat less than one knot.

Earlier experiments with conventional drift bottles in this general area suggest that there is a westerly set from Nantucket Shoals, inshore of the area where the buoy was adrift, at rates of two to five miles per day; and another drift more or less along the 100 fathom contour at slightly greater speeds. This one experiment with the transponding drift buoy suggests that the waters between these two westward drifts undergo an anti-cyclonic irrotational motion; one quite erratic in it's rates of movement and direction, suddenly speeding up and gradually slowing down and nearly completing it's orbit in two weeks.

Six more transponding drift buoys are under construction. Plans are shaping up with the Fish and Wildlife Service to employ these buoys in the Bay of Fundy this autumn and on Georges Bank next spring. The development of these buoys has been supported under a Navy contract and the employment of them to study drift will be under the contract with the Fish and Wildlife Service in the study of the environment of fish.

Currents and Tides

The tide gauge house which has been standing for 25 years on the inside edge of our dock has been moved to a stronger location and placed about ten feet higher than formerly.

Almost all tide gauges along the coast, including our own, were put out of action during hurricanes, a fact which proved most bothersome for our studies of water levels associated with hurricanes.

The Agassiz Medal of the National Academy of Sciences was presented recently to Dr. A. C. Redfield in recognition of his distinguished contributions to oceanography.

The Agassiz Medal has been awarded 25 times in 45 years. Other recipients of the honor in this Institution are: Dr. H. B. Bigelow, Dr. C. O'D. Iselin, and Dr. M. Ewing.

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